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THE JANUARY WARM SPELL AND ASSOCIATED LARGE-SCALE CIRCULATION CHANGES

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ABSTRACT

Recurrent departures of mean weekly temperatures from a smooth seasonal trend during the past several decades in the northeastern United States are shown to be a manifestation of a shift in the planetary circulation. The geographical extent of these temperature excursions from normal and the synoptic pattern through which they occur are discussed. Secular changes in the amplitude of the warm spell which occurs in January over the northeastern United States are directly related to simultaneous changes in the planetary circulation and are not independent fluctuations.

1. INTRODUCTION

Recurrent departures of temperature from a monotonic seasonal trend drew considerable attention from meteorologists during the 19th and early 20th centuries. An extensive bibliography of these early studies, which related mostly to European climate, was published by Talman [18] in 1919; it contains 144 entries. In the same issue, Marvin [12], who at that time was Chief of the U.S. Weather Bureau, examined climatological data from several North American stations and concluded that they did not support the popular concepts of January Thaw, Indian Summer, or of other similar anomalies.[1] He offered three observations in support of this conclusion: 1. A harmonic analysis of mean weekly temperatures indicated that all components other than the first one or two were negligibly small; 2. The departures of mean weekly temperature from these first harmonics, averaged over successive 15-yr. periods, appeared to be poorly correlated from period to period; 3. No physical phenomenon was known which could explain recurrent departures from a march of temperature closely similar to the annual variation in incident solar radiation. For a long while after 1919, professional interest in North American anomalies remained slight even though the folklore persisted. In Europe, the principal development was the concept of "Grosswetterlagen" (extended periods of dominant weather regimes) by Baur [1] who related the occurrence of these to conditions found on certain "key days."

In recent years occasional papers concerning North American anomalies have been published; they are about equally divided between those that deny and those that proclaim the validity of the concept. The latter, in general, deal with local phenomena and do not offer a systematic rebuttal to Marvin's arguments; the most notable exception is a project report by Bryson and Lahey [3]. Considerable differences exist among these recent papers concerning the time span of anomalies. In this paper relatively long temperature variations will be considered. Bryson and Lahey [3] refer to these as "primary singularities." Following Landsberg [10], the term "spell" is used in this paper in order to indicate a looser coupling between the calendar and meteorological phenomena than that usually implied by the terms "singularity" or "anomaly." Within that frame of reference, the present article will reexamine Marvin's arguments in the light of longer climatological records and of atmospheric circulation concepts developed since 1919.

[1] The author is indebted to Mr. Marvin Burley, Weather Bureau State Climatologist, Wisconsin, for directing his attention to this article.

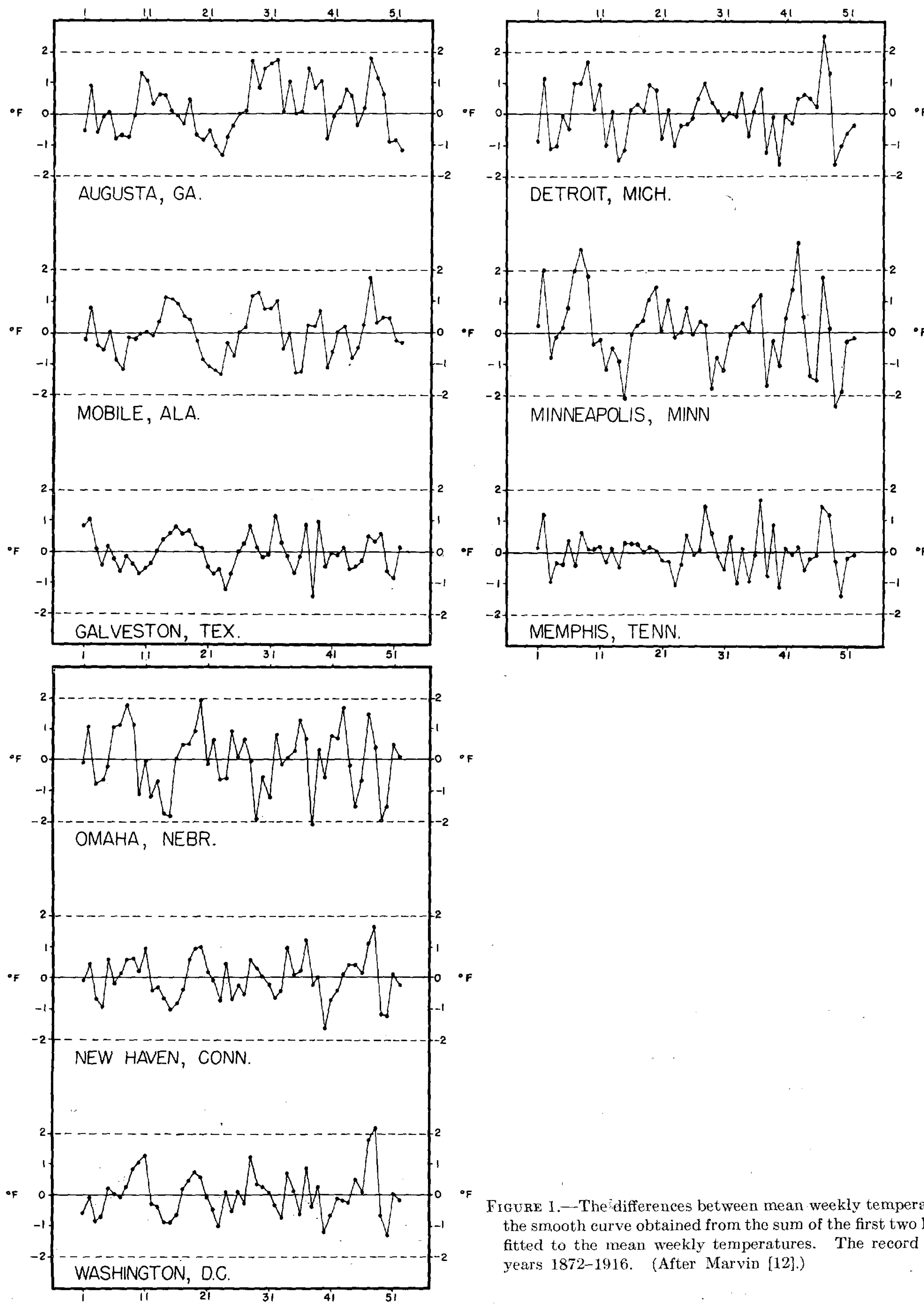

FIGURE 1.—The differences between mean weekly temperatures and the smooth curve obtained from the sum of the first two harmonics fitted to the mean weekly temperatures. The record is for the years 1872–1916. (After Marvin [12].)

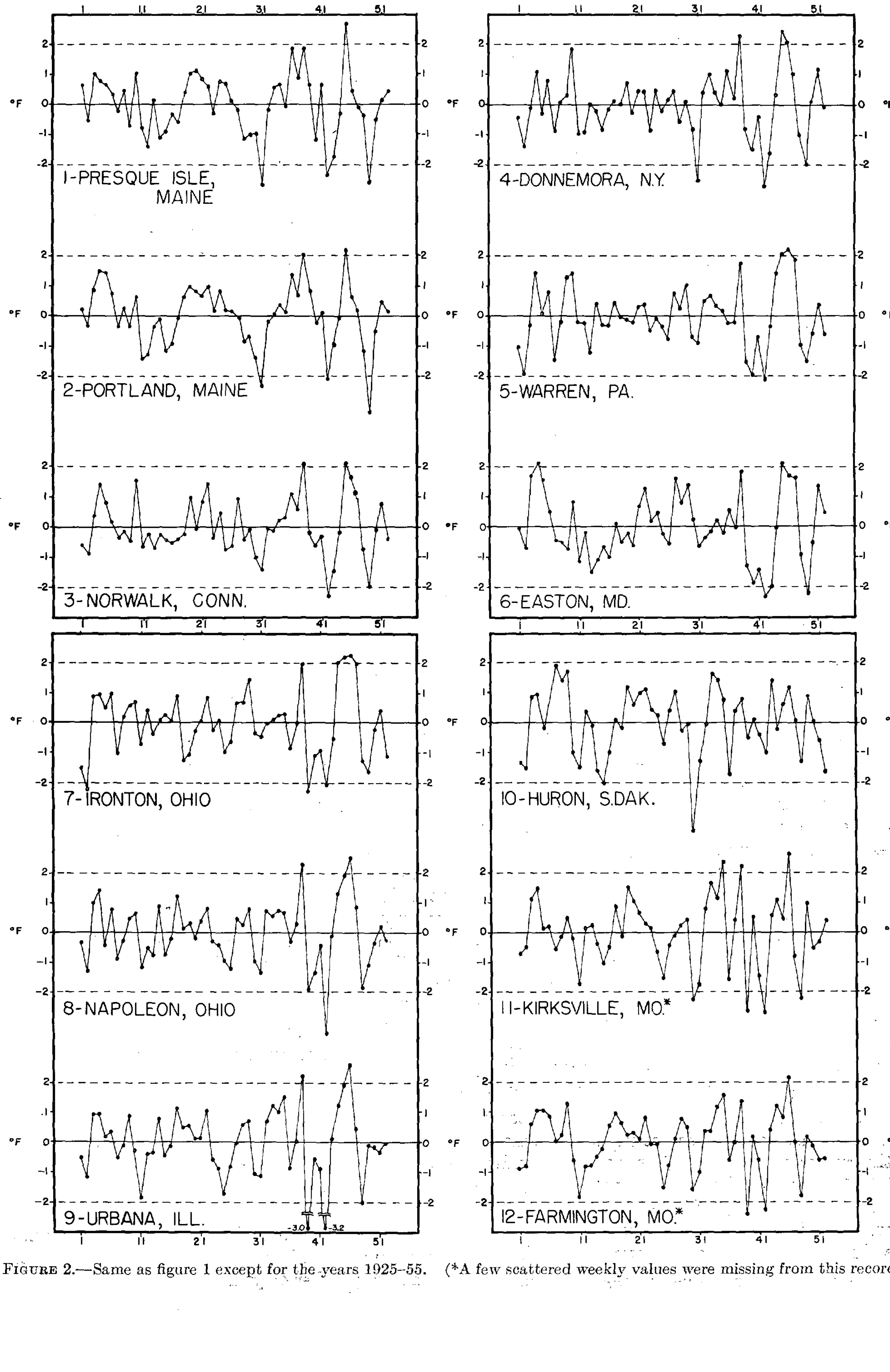

FIGURE 2.—Same as figure 1 except for the years 1925–55. (*A few scattered weekly values were missing from this record.)

The temperature data will consist entirely of mean weekly values. They were obtained primarily through the cooperation of members of the Northeast and the North Central Regional Committees of Agricultural Research Stations. There has been some recent interest in recurrent departures from "normal" in other climatic elements such as rainfall (e.g., [10]) or depth of snow on the ground,[2] but practical considerations limited this study to temperature only. There is also some evidence that weekly minimum temperatures display larger departures from seasonal trend than do maximum or mean temperatures, but only the latter are considered in this paper.

Weekly statistics have the advantage of reducing the volume of numbers to be processed and, in addition, represent a desirable amount of smoothing of the basic information. Following current practice the year is divided into 53 weeks with week 1 starting March 1 and week 52 running from February 21 to 27. "Week" 53, which consists of February 28 and February 29 in leap years, was not used in the computations nor is it shown in the figures.

The first two harmonics in the annual temperature cycle at each location were computed from data extending over the longest time interval for which they were available. The adequacy of the first one or two harmonics in representing the undisturbed annual temperature cycle was shown by Marvin for data taken in North America; higher harmonics in the temperature cycle have been shown to be small in other areas of the world also [4]. Departures from these harmonics will be referred to as "excursions" in this paper.

Wahl [19], [20] has drawn attention to a relationship between mean daily temperatures and wind direction at Boston, Mass. When he stratified his temperature statistics by zonal index values, the occurrence of anomalously warm periods in January appeared to be favored by a low index value. Differences in the sea level pressure pattern over the North Atlantic were related to anomalous temperatures in the eastern United States and northwestern Europe by Wahl [19] and by Ehrlich [6]. In the present paper, planetary circulation features at 700 mb. will be examined for a relationship with recurring temperature departures from normal over wide areas.

2. WEEKLY TEMPERATURE DATA

For ease of comparison with later statistics, many of Marvin's data are reproduced in figure 1 of this article. The 7-day intervals chosen by Marvin are not those defined in the introduction, but the small difference is not of great importance to the discussion which follows. Each of the curves refers to a 45-yr. record extending from 1872 to 1916 except those for Augusta, Ga. (1874–1916), and New Haven, Conn. (1873–1916).

In general, the inter-weekly changes in temperature excursions during this early period were larger in the cold season than in the warm, but no single value is so far removed from the others as to be of obvious significance. This is especially true of the data for western and southern locations. In the Northeast (New Haven, Conn., Washington, D.C., Detroit, Mich.) a rapid cooling from a relatively warm week (week 48, January 22–28) to weeks 49 and 50 is interesting because it is the largest change between weeks and because it occurs near the traditional time of the "January Thaw." This peculiarity can be traced toward the south where it decreases in amplitude and toward the west where it becomes indistinguishable from several other inter-weekly changes of equal or larger magnitude. The "warm spell" also appears to have occurred slightly earlier in the west with perhaps half a week lag between Detroit and New Haven.

When the data were divided into three independent 15-yr. periods, this peculiar January temperature behavior was found only in the third period, 1901–1916. From this evidence, Marvin concluded that chance and the selectivity of human memory, rather than physical causes, explained the January Thaw. He predicted that longer records would show smaller excursions from the annual cycle.

The relatively recent interest [3] in sudden circulation and weather changes in middle and late June draws our attention to temperature changes near week 16. At the Midwestern stations (Omaha, Nebr. and Minneapolis, Minn.) this is a time of relatively rapid recovery from one of the largest negative excursions of the warm seasons. In the Northeast the changes are similar but reduced in amplitude, while the southeastern temperature changes are quite dissimilar. At the same two Midwestern stations, weeks 28 to 31 show an interesting negative peak that may be associated with the prelude to Indian Summer described by Bryson and Lahey [3].

Turning to more recent and independent information, figure 2 presents the temperature excursions at several stations in the Northeast and North Central United States, during the period 1926–1955. It is immediately obvious from figure 2 that weeks 45 and 46 (December 24 to January 6) were considerably warmer during these years than were the preceding and following two or three weeks. This "warm spell" occurred from one to two weeks earlier than the corresponding "spell" in the years 1872–1916 as described above. The warm spell was also more pronounced than in the earlier record, but this could be due to the shorter time span of the later records in accordance with Marvin's conclusion.

Temperature fluctuations in an interval near week 16 were also similar during the two periods. In the North Central region (e.g., Huron, S. Dak.) week 16 is a time of recovery from a cool spell; the recovery is less distinct although still present in the extreme northeast (e.g., Maine), but the excursions are quite dissimilar in Missouri. The cool prelude to Indian Summer during week 31 was more extreme and more extensive in the later 30 years than in the earlier 45 years.

[2] Private communication from Dr. B. Dethier, Cornell University, Ithaca, N.Y.

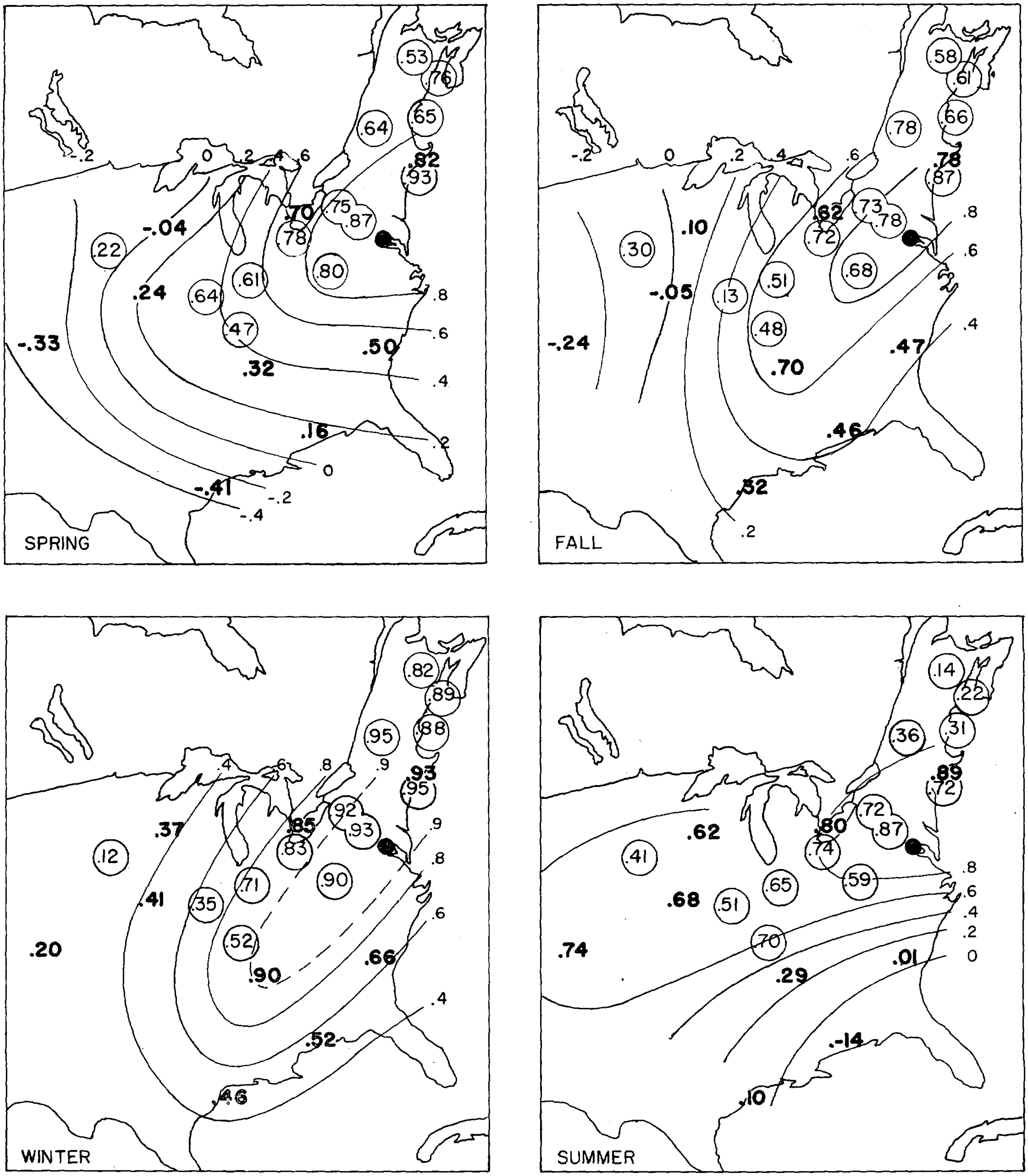

Figure 3.—Correlation coefficients between temperature excursions at (a) Washington, D.C. and Marvin's other stations, 1872–1916 (in heavy print); (b) Easton, Md., and other selected locations, 1926–55 (in light print and circled). The seasons are 13 weeks each starting with spring from week 1 to week 13 inclusive.

As one could expect, excursions at neighboring stations are closely related to each other. This was noted by Marvin in 1919 and again by Bingham [2] in 1961. Temperature abnormalities, on this time scale at least, are obviously large-scale phenomena related to peculiarities of large atmospheric circulation systems rather than to topographic or other local influences.

As a measure of the scale of the phenomena producing these observed departures from a smooth curve, the correlations between excursions at each station were computed. The correlation coefficients between Washington, D.C., and Marvin's other stations are shown in figure 3. The corresponding distribution during the period 1926–55 is represented by the correlations between excursions at Easton, Md. and those at several other locations in the northern United States. Isopleths of correlation were drawn for Marvin's data since they had a wider geographical distribution and since they covered a longer period of time.

The correlation coefficients are larger for the earlier period than for the later. This is attributed to the somewhat longer length of the earlier period which presumably reduced random local effects.

The winter season correlation coefficients are positive throughout the area covered by the maps. In general the absolute values of the winter coefficients are larger than their counterparts in other seasons. Figure 3 reveals a tendency for higher correlation coefficients along an axis that changes direction with the season. The most significant wintertime temperature excursions from normal in the northeastern United States are apparently associated with Gulf Coast storms which track northeastward along the Appalachians. Summer temperature abnormalities along the Mid-Atlantic coast occur in conjunction with abnormalities in the Central Plains most likely because of the zonal orientation of the mean summer position of the polar front. The distribution of fall correlation coefficients resembles the winter pattern; the springtime distribution is the most symmetrical of the four.

While these figures are indicative of the manner by which the excursions were produced in the northeastern United States, they do not outline the area in which the atmospheric mechanism responsible for the excursions operates. On the contrary, evidence compiled by Rebman [15] indicates that a west-coast singularity is closely related to the northeastern January Thaw. A "warm spell" in early January on the west coast may also be found from the weekly mean temperature data of Schick [16] covering the period 1916–35. Several articles have been written on the existence of anomalies in the weather over the British Isles and Europe during January. From these, and from our knowledge of the simultaneous adjustments in the long-wave patterns around the hemisphere that occur in response to vigorous developments over one area, it may be inferred that any recurrent mechanism which would account for the observed temperature excursion in

TABLE 1.—*The correlation coefficient between temperature excursions at pairs of stations during two independent periods*

	Period	Spring	Summer	Fall	Winter	Year
Washington, D.C. Easton, Md.	(1872–1916) (1926–1955)	−0.17	0.12	−0.17	0.40	0.16
Detroit, Mich. Napoleon, Ohio	(1872–1916) (1926–1955)	−.48	.09	−.23	.35	.04
New Haven, Conn. Norwalk, Conn.	(1873–1916) (1926–1955)	−.34	.56	−.00	.35	.21

the northeastern United States may be detected in parameters which describe and trace the evolution of the planetary circulation. An elaboration of this point follows some further comments on the temperature records.

Since the correlation coefficients between excursions at nearby stations are large, it is not unreasonable to compare excursions during the two periods at stations in such close proximity as, for example, Easton, Md., and Washington, D.C. Three such pairs of stations are compared in table 1. While the coefficients are rather small, the winter values, at least, are positive and consistent from pair to pair.

3. LONGER RECORDS

If the temperature excursions discussed above arose by chance, the passage of time would tend to reduce their amplitude as Marvin predicted. Figure 4 shows departures from each of the first two harmonics at Storrs, Conn. and at Easton, Md. during 60-yr. periods. The warm spell at Storrs during the period 1890–1955 (except 1920–25 for which data are missing) is more pronounced than at New Haven during 1873–1916 or at Norwalk during 1926–55. Similarly, the warm spell at Easton, Md. is not any less pronounced in figure 4 than in figure 2.

The intensity of the January warm spell may be characterized by the difference between the mean weekly temperatures during the spell and the average mean weekly temperatures before and after the spell. One such definition which will be adopted here is:

$$A=\frac{T_{45}+T_{46}}{2}-\frac{T_{42}+T_{43}+T_{48}+T_{49}}{4}-N$$

where A is the amplitude of the winter temperature cycle, T_w is the weekly mean temperature for week w, and N is the value of the first two terms when the temperatures given by the first harmonic of long-period means are inserted. Since weeks 45 and 46 are cooler than the average of weeks 42, 43, 48, and 49 in the first harmonic at most locations, N is usually negative.

Values of A at Easton, Md., are listed in table 2 by climatological year for the period 1893–1961. The average value of A at Easton (2.4° F.) is significantly different from zero at the 0.01 level for as few as 11 degrees of freedom according to Student's "T" test. The actual number of degrees of freedom in the data is uncertain in

TABLE 2.—*Amplitude (° F.) of the January "warm spell" at Easton, Md.*

$$A=\frac{T_{45}+T_{46}}{2}-\frac{T_{42}+T_{43}+T_{48}+T_{49}}{4}+1.4$$

1893	2.9	1916	6.8	1939	−1.2
94	1.6	17	−0.6	40	−4.0
95	−14.8	18	−8.7	41	−9.1
96	6.8	19	1.5	42	1.2
97	7.9	20	3.6	43	−2.2
98	4.4	21	2.8	44	1.4
99	2.8	22	4.1	45	13.3
1900	5.2	23	−4.4	46	0.5
01	1.8	24	−2.1	47	5.7
02	−5.7	25	0.9	48	5.0
03	−4.2	26	−3.3	49	9.4
04	9.4	27	5.8	50	6.3
05	2.6	28	1.7	51	4.4
06	15.8	29	10.5	52	2.4
07	5.3	30	1.8	53	−2.9
08	0.7	31	4.4	54	6.3
09	−1.4	32	6.6	55	4.0
10	7.4	33	6.6	56	−8.0
11	−12.2	34	12.7	57	−9.4
12	7.6	35	13.8	58	2.3
13	−9.4	36	8.9	59	2.8
14	8.8	37	−2.4	60	14.7
15	−3.8	38	9.3	61	1.4

view of the tendency for amplitudes of like sign to occur in runs. This suggests the presence of "regimes" or lack of independence of the amplitude in successive years. As a matter of fact, a nonparametric test for runs (Siegel [17]) was made. It indicates that from 1917 to 1961 the observed frequency of alteration of signs of the departure of the amplitude from its mean would occur by chance in only 2 percent of random samples of similar length. The observed frequency of runs from 1893 to 1909 would occur in only 4.5 percent of random samples of similar length. Further discussion of secular changes in the warm spell follows in the next section.

The temperature excursions in the 89-yr. record for Edmonton, Alta. which are shown in figure 5 are interesting for several reasons. The very large value of the second harmonic at Edmonton compared to those at the east coast stations shown in figure 4, is the result of latitude and of continentality in the Edmonton climate. At Edmonton week 45 is warmer than the preceding or following weeks, but, more significantly, it is followed by a precipitous temperature drop in week 46 which is simultaneously a minimum in both the first and second harmonics and the time of a negative excursion.

The negative temperature excursion which occurs about week 48 in the northeastern United States and which terminates the cycle that we have called the January warm spell is thus apparently related to the march of winter in the northwestern part of the continent. The temperature record at Edmonton is in accord with the synoptic pattern hypothesized in the previous section to explain the winter correlation coefficient pattern in anomalies over the eastern United States. It confirms the presence of a pool of cold air which could supply the temperature contrasts necessary for cyclone development and for the cold outbreak which could follow the last in a series of these cyclones. The positive excursion at Edmonton during weeks 42 and 43 occurs at the same time as the negative excursion in eastern United States which initiates the warm spell cycles. It is presumably a manifestation of a temporary exhaustion of the Arctic supply of cold air which had been drained southward.

While only short-term temperature records are available for stations much farther north than Edmonton, the data for Whitehorse, Yukon Territories, also shown in figure 5, are in accord with the picture we have just outlined.

Further support for the hypothesized synoptic mechanism which would account for the warm spell is found in the charts of 5-day normal mean sea level pressure prepared by Lahey, Bryson, and Wahl [8]. During late December and early January, a trough appears to migrate from the Mid-West across the east coast of the United States; simultaneously, pressure over the Yukon rises. The trough is then followed along the east coast by very pronounced northwesterly flow as a result of a strong pressure rise over the United States and a strong pressure fall over the western Atlantic.

4. THE "CHANGE IN PHASE"

Most meteorologists part company with the devotees of cycles and periods in meteorology when the latter invoke a "change of phase" argument to explain the absence of the postulated periodicities in independent data. Just such a "change in phase" has been ascribed to the January Thaw by Lautzenheiser [11]. Its counterpart is to be found in the weekly mean temperature data as well as in the daily temperatures to which Lautzenheiser referred. If the "change of phase" is used solely as an explanation, and is itself left unexplained, it is indeed a serious weakness in any argument for the existence of cycles or periods. On the other hand, if the change of phase can be shown to be related to other observed and accepted phenomena, it ceases to be a liability and becomes another demonstration of the physical reality of the cycle. As an example of this latter possibility, Namias [14] showed that a change in periodicity of cyclogenesis observed during the winter and spring of 1953 was related to abrupt but logical rearrangements of the planetary circulation incident to the change in season.

Figure 6 shows the temperature excursions at Easton, Md., during six consecutive 10-yr. periods and the five overlapping decades. We observe that at the turn of the century, week 47 was the peak of a cycle corresponding to the January warm spell discussed above. In the interval 1916–25 and again during 1936–45 this cycle was almost completely absent. Between these periods the cycle appeared somewhat broader with a maximum during weeks 45 through 47 and, in the last decade shown, the shift to an earlier maximum has progressed even farther. The shift to an earlier maximum appears even more obvious if one looks at the decades which overlap these periods. The maximum appears in weeks 48, 47, and 45 in the 1910's, 1920's, and 1930's, respectively.

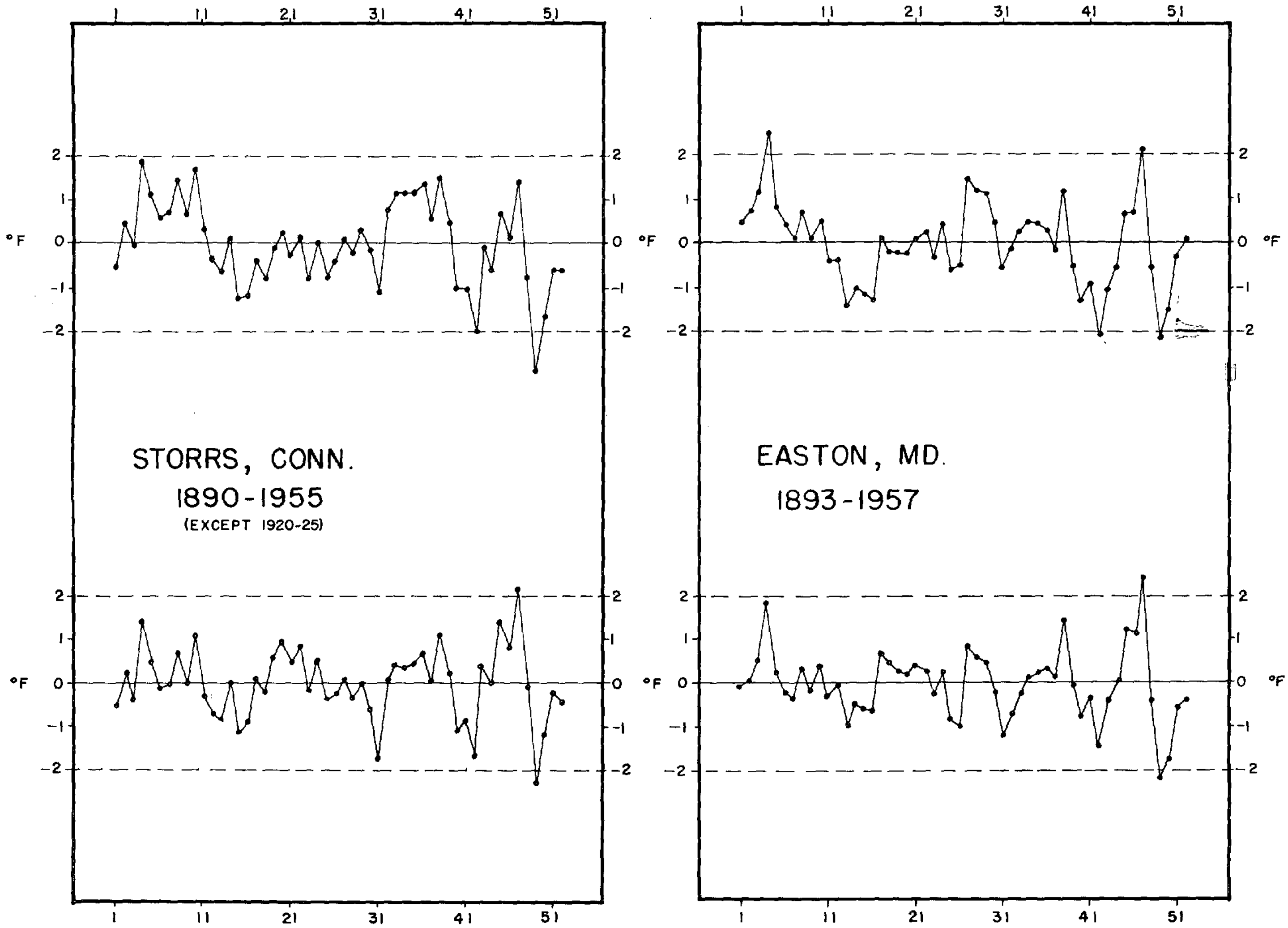

FIGURE 4.—The difference between mean weekly temperatures and the first harmonic fitted to these temperatures (upper curves). Excursions from the sum of the first two harmonics (lower curves).

Under the hypothesis that these temperature fluctuations are not random but are, instead, a manifestation of some recurrent adjustment in the planetary circulation systems, the "change of phase" should be related to secular variations in the latter. No single parameter can fully describe the state of the planetary circulation, but the extent and/or intensity of certain quasi-permanent circulation features can be used as indicators of the presence or absence of some (ill defined) changes. For example, Kraus [7] observed an intensification of the North Indian summer-monsoon Low and an increase in the seasonal pressure oscillation over the interior of Eurasia. From these he inferred an intensification of the standing circulation of the Northern Hemisphere. It is pertinent to the present discussion to note that both phenomena observed by Kraus show a sharp change during the decade 1910–20. Kraus also demonstrated that temperature changes in the Far East and over Europe occurred in association with this circulation change.

Several indices of circulation have been examined by Lamb and Johnson [9]. Figure 7 reproduces their data for the 10-yr. running mean of: (a) the over-all range of mean pressure over the North Atlantic in January; (b) the average temperature differences between Trinidad, B.W.I., and Toronto, Canada in January; (c) the average latitude of the Azores High during January. These can be compared with the fourth curve in figure 7 which is the 10-yr. running mean of the amplitude of the January warm spell at Easton, Md.

It is apparent at first glance that the amplitude of the warm spell is at least as well correlated with each of the other curves as the latter are with each other. Numerical values of correlation coefficients would be meaningless,

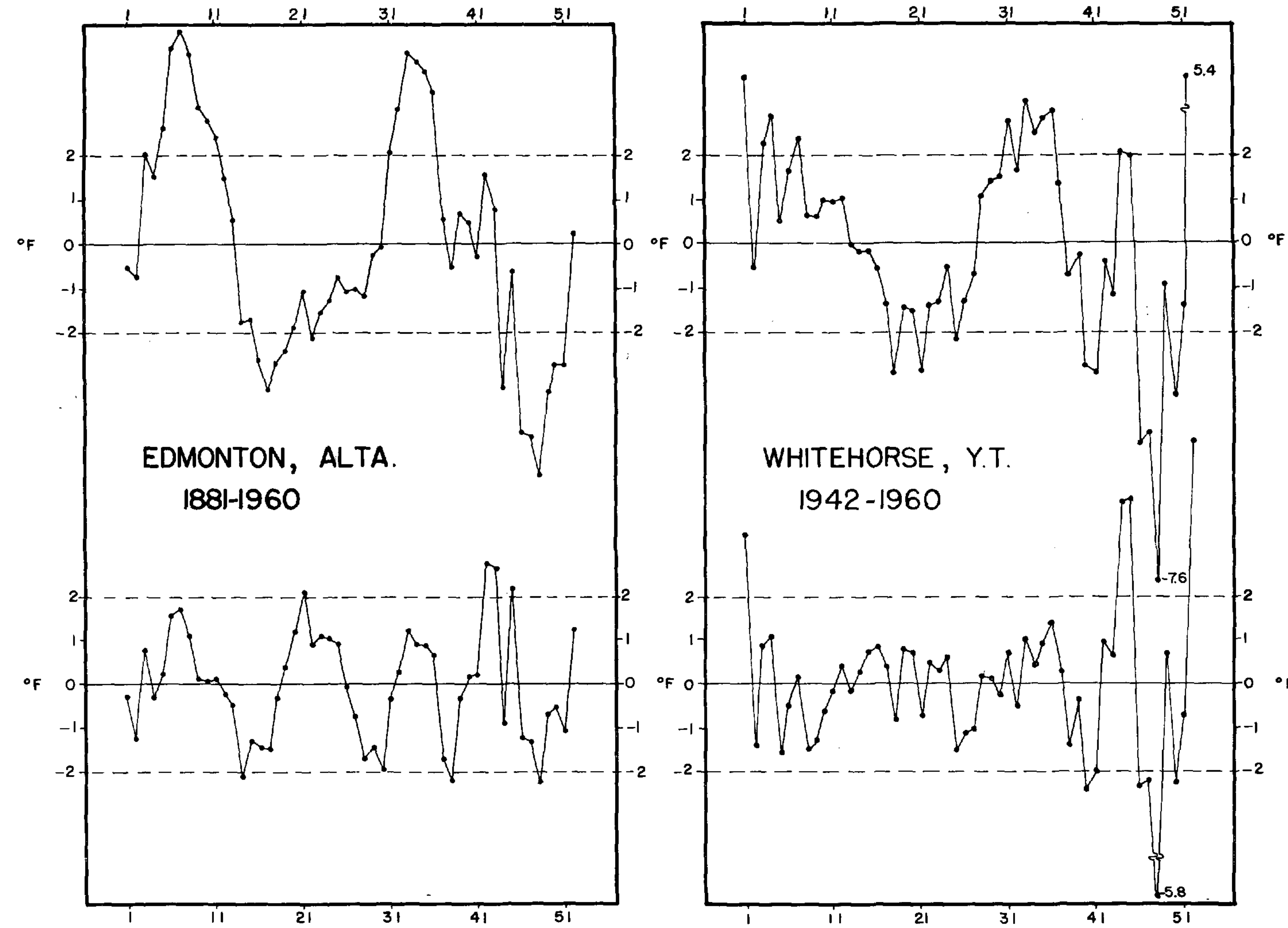

Figure 5.—Same as figure 4.

however, since the number of degrees of freedom in the data has been drastically reduced by the use of 10-yr. running means. (Lamb and Johnson published only these figures and 40-yr. running means.)

The negative correlation between the north-south temperature gradient (fig. 7b) and the amplitude of the warm spell is in agreement with Wahl's observation that the January Thaw was more pronounced in years of low zonal index. Since temperature excursions at Toronto and Easton are correlated (fig. 3) these two quantities have an element in common to the extent that the excursions are related to the mean January temperature at the same point. The strong positive correlation between the latitude of the Azores High (fig. 7c) and the amplitude of the warm spell complements the observation of Wahl and Ehrlich that the occurrence of anomalous temperatures in the eastern United States and western Europe is accompanied by anomalous pressure patterns over large areas of the North Atlantic. The fact that the overall range in mean pressure over the North Atlantic (fig. 7a) is rather poorly correlated with the other curves is believed to be due to the inclusion of too many variables in the derivation of this quantity.

From the above, it has been concluded that the January warm spell is symptomatic of the state of the planetary circulation and that secular variations in its amplitude, far from casting doubt on its reality, actually add to its significance.

5. ABRUPT CHANGES AT 700 MB.

Evidence concerning the irregular behavior of the planetary circulation has been derived from the 700-mb. zonal wind profile over the east coast of North America and over the western half of the Northern Hemisphere.

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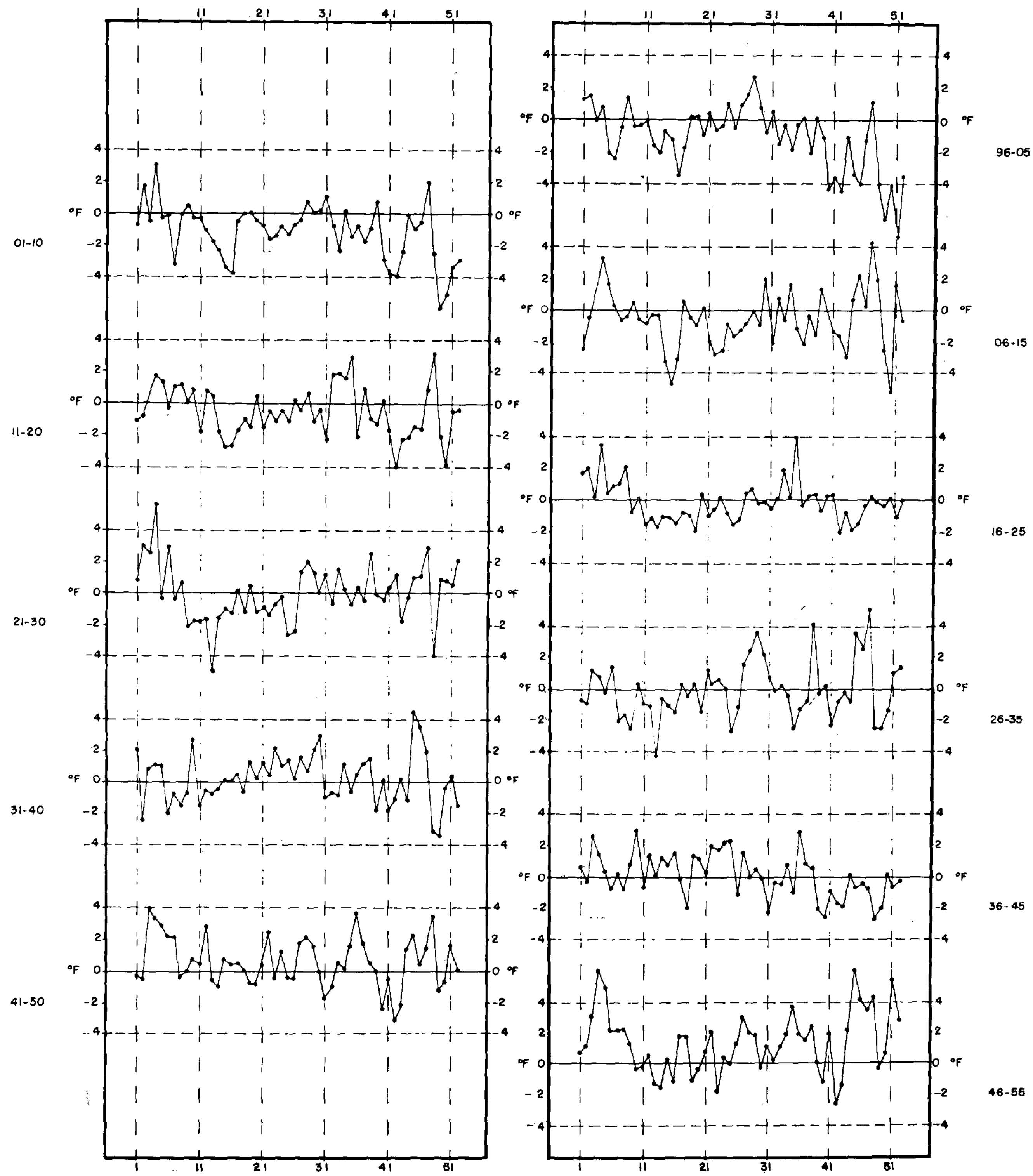


FIGURE 6.—Temperature excursions at Easton, Md. averaged through various 10-yr. intervals. All excursions are from the sum of the first two harmonics fitted to the mean weekly temperature averages over the entire 60 years.

Winston [21], using 7 years of 5-day mean maps, demonstrated the existence of significant differences between zonal wind profiles so obtained and those determined from mean monthly maps. His zonal wind profiles represented the flow from 0° to 180° longitude via North America. Figure 8 shows the zonal wind profile during 16 months of January across the 30° longitude band from 60° to 90° W., i.e., across the east coast of North America. The data consist of twice-daily values of geopotential read at a diamond grid of points, the diamonds having

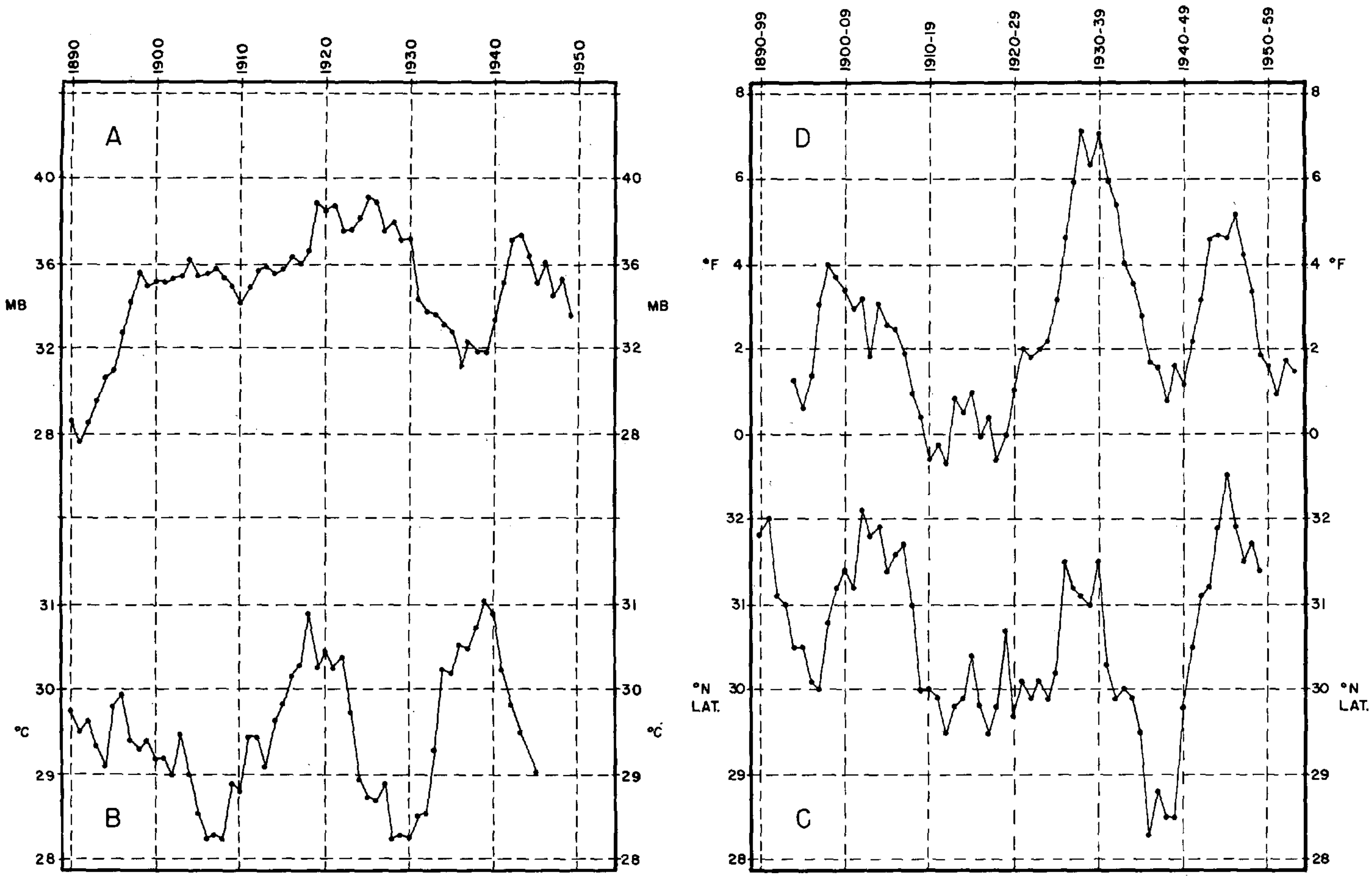


Figure 7.—Ten-year running mean of (a) the overall range of mean pressure over the North Atlantic, (b) the average temperature difference between Trinidad, B.W.I. and Toronto, Canada, (c) the average latitude of the Azores High, and (d) the amplitude of the January warm spell at Easton, Md. Curves a, b, and c taken from Lamb and Johnson [9].

axes of 10° latitude and 10° longitude. The analyses were the standard U.S. Weather Bureau maps maintained on file by the Extended Forecast Branch of the National Meteorological Center.

In figure 8, an abrupt shift in the latitude of the west wind maximum occurs during the second week in January. It is preceded by the formation of a well-defined peak in the west wind in the band 35° to 40° N. and culminates in a somewhat weaker maximum 10° latitude farther north. The reason for this anomalous behavior was sought in daily 700-mb. maps prepared from the same data that were used to derive the zonal wind profile. A few of these maps are shown in figure 9. The climatology of aerological data which has hitherto been published consists exclusively of monthly, seasonal, or yearly means. Since the daily mean maps of figure 9 are based on only 16 individual days each, the detail they contain may be lacking in significance. On the other hand, the remarkably large differences in the planetary flow that are observed between these maps cannot be dismissed as detail. The change in the mean daily 500-mb. map between January 20 and 27 was associated with a singularity by Dickson [5].

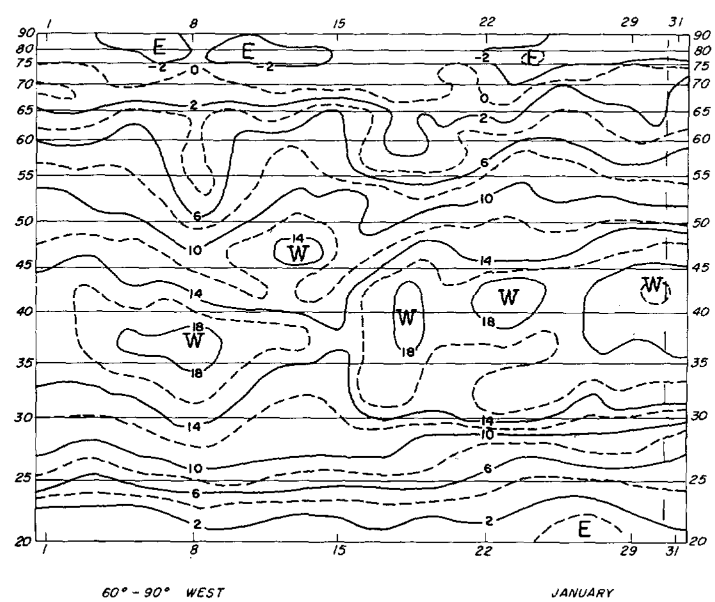
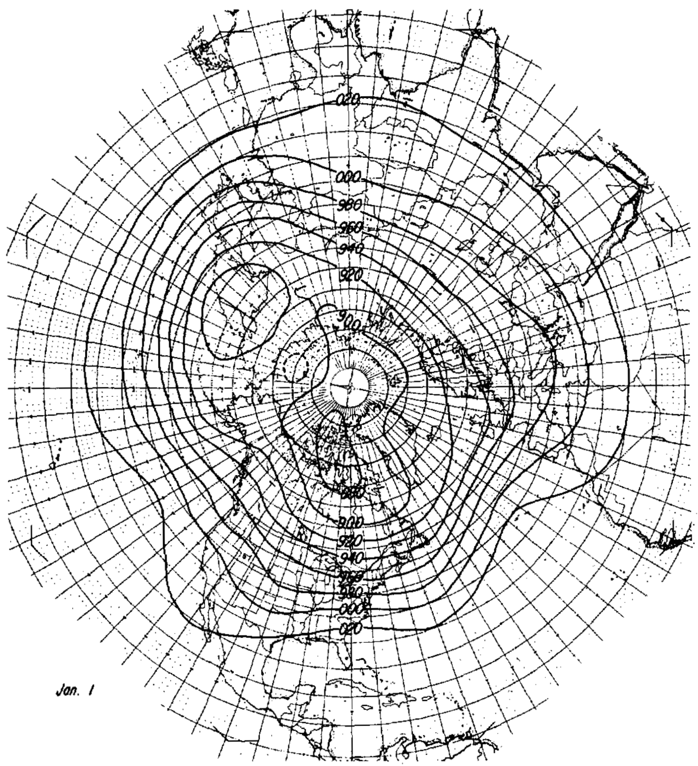
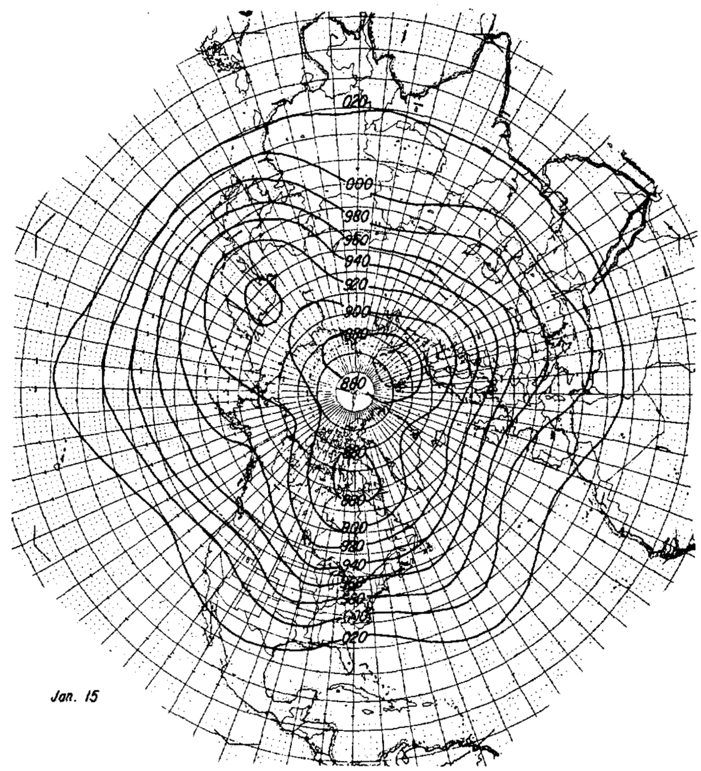


Figure 8.—The westerly component of 700-mb. winds over the east coast of North America during January averaged over the period 1947–62.





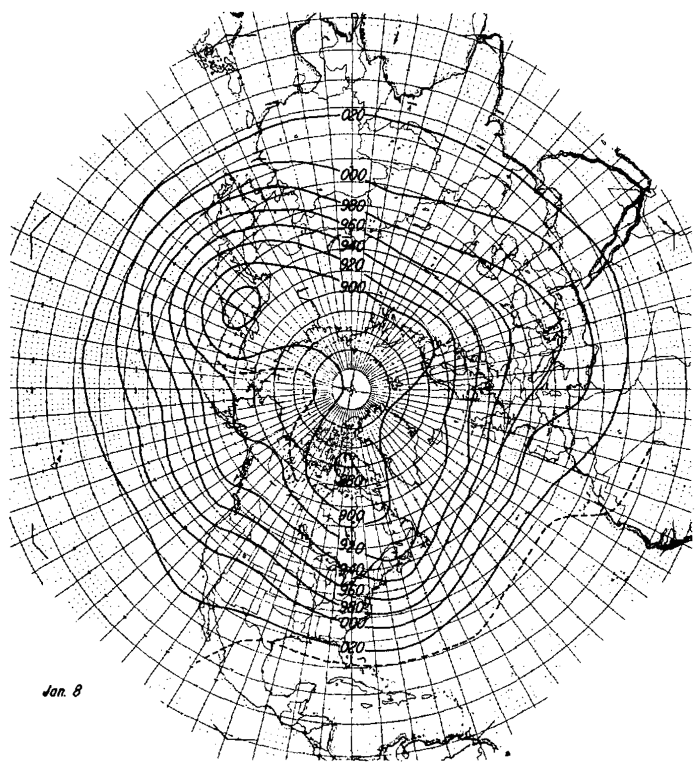


FIGURE 9.—Mean 700-mb. maps for the 1st, 8th and 15th of January, based on twice-daily analyses during the period 1947–62. Data from the Extended Forecast Branch of the National Meteorological Center.

Some of the differences that exist between the monthly mean maps for December and for January can also be seen between the daily maps for January 1 and January 15. The most obvious of these differences are the formation of a pronounced ridge over Alaska which previously had been under a broad Pacific trough, and the intensification over Central Europe of a trough which had previously been over the British Isles. The transition period is illustrated by the map for January 8. On that date a sharp trough is found along the east coast of North

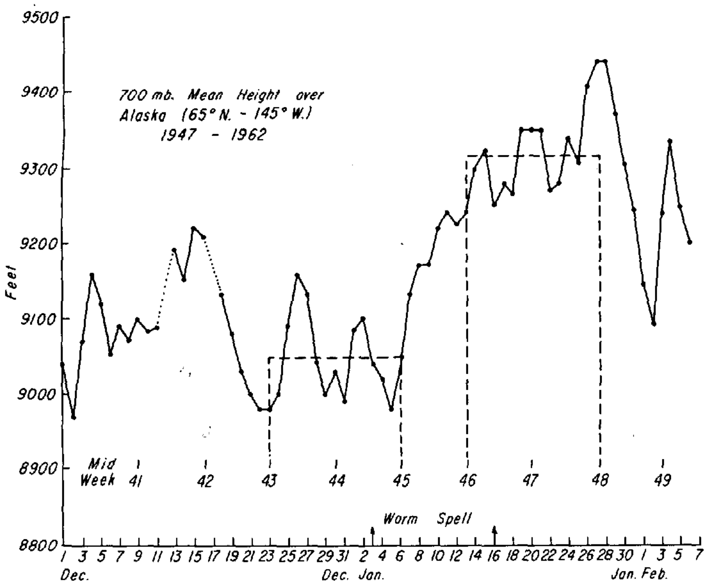


FIGURE 10.—Daily mean values of 700-mb. height near Fairbanks, Alaska. The middle days of the climatological weeks discussed in the text are shown here. Mechanical imperfection on the magnetic tapes containing the original data prevented the determination of mean values for December 12 and 17.

America whereas in the same region during preceding and following weeks there is found on the daily mean maps the flat base of a broad trough with extensions into the Midwestern States and into the western Atlantic. It is the formation of this sharp trough through the east coast region that produced the abrupt shift in the latitude of the westerlies seen in figure 8.

The abruptness of the circulation change in January and its relationship to the January warm spell is further illustrated by figure 10 wherein daily mean values of the 700-mb. height at 65° N., 145° W. (near Fairbanks, Alaska) during 1947 to 1962 are plotted. The warm temperature excursions over the northeastern part of the United States, which occurred during weeks 45 and 46 in these years (cf. fig. 6 and table 2), are seen to be coincident with a rapid change in regime at 700 mb. over Alaska. During the 15 days prior to the middle of week 45 the average 700-mb. height at 65° N., 145° W. was 9,047 ft.; during the 15 days following the middle of week 46 the average height there was 9,318 ft. This 6-day height change was slightly less than the average standard deviation of the daily values during December.

The formation of the trough which appears along the east coast on the map for January 8 certainly implies surface cyclogenesis. The trough undoubtedly first appears much farther west than its position at time of maximum amplitude (January 8). This would be in agreement with the synoptic pattern implied by figure 3 and would account for the transport of warm air into the northeastern United States during the warm spell. When a low pressure center moves northeastward on the continental side of the Appalachians and an upper-level trough is both deepening and moving eastward, it is common to observe further cyclogenesis along the Carolina coast. This second center usually becomes the dominant system and injects relatively mild (and moist) Atlantic air into the original center over the Northeastern States. This may also contribute to the relative warmth of the early part of January. In any case, the building of the Alaskan 700-mb. High must cause a downstream reaction which will have a surface counterpart closely linked to the observed temperature excursions. Conversely, the late December disappearance of the Gulf of Alaska Low in the 5-day mean surface maps of Lahey, Bryson, and Wahl [8] implies a correspondingly sudden change at that time in the upper-level planetary circulation during the years from which their data were taken (1907–13 and 1925–37).

It is noted also that the map for January 8 in figure 9 shows a minor trough off the Pacific coast of the United States where a ridge is found on the map for the 1st and for the 15th of January. This is very likely associated with the warm spell observed on the west coast mentioned earlier. It is plausible that the shift of the European trough from the British Isles to Central Europe is related to anomalous January weather in England to which reference was also made earlier.

It appears, then, that an adjustment of the planetary circulation from what might be called an early winter stage to a late winter stage can satisfactorily account for the interruption of winter by a primary singularity which appears as a "warm spell" over the northeastern United States. The timing of the adjustment undoubtedly is dependent upon the prior state of the planetary circulation in a manner similar to the variation in the primary index cycle discussed by Namias [13]. The temperature data from Easton, Md. (fig. 6) suggest that over several decades the time of the interruption may range over a couple of weeks. The January 8 date is, therefore, interpreted only as the preferred time of adjustment in the planetary flow during *this particular 16-yr. interval.*

6. SUMMARY AND CONCLUSIONS

The course of winter as seen in mean weekly temperatures involves two stages in the northeastern United States. The stages are separated by a "warm spell" which occurs in early January. The geographical extent of the warm spell indicates that Gulf Coast cyclones tracking along the Appalachians are the vehicle by which warm air is transported into the region. The time of the warm spell is close to that of minimum temperature over the northwestern part of North America so that potential energy in the atmosphere over North America and vicinity is at a maximum at this time with a long-wave trough migrating across the east coast of North America. Although the timing and amplitude of the warm spell are variable, they are related to the state of the general circulation of the atmosphere during any particular season and undergo secular changes that parallel changes in other indices descriptive of the general circulation.

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